APPLIED AND ENVIRONMENTAL MICROBIOLOGY, Nov. 1977, p. 541-546
Vol. 34, No. 5

Printed in U.S.A.

Effect of an Activated Carbon Filter on the Microbial Quality of Water

J. V. FIORE[1]* AND R. A. BABINEAU[2]

AMF Technical Center, AMF Incorporated, Stamford, Connecticut 06907,[1] and AMF Cuno Division, AMF Incorporated, Meriden, Connecticut 06450[2]

Received for publication 6 May 1977

Recently, there has been growing concern that microbial health hazards can be increased by the use of activated carbon filters in domestic water systems. The present study was undertaken to investigate the effect of carbon filters on the microbial content of water. Results indicated that the microbial content of filtered and unfiltered water increased to about the same level on overnight standing and, in both cases, was reduced by flushing the next day. In addition, the use of activated carbon for the filtration of contaminated well water over a period of 11 weeks had no effect on the total or coliform count. Under use conditions, activated carbon filters were found to have no significant effect on the number of bacteria present in the water.

Activated carbon has been used for over 15 years as a means of generally improving the quality of household drinking water by removing objectionable tastes and odors as well as dirt, rust, and sand. During this period of time, it is estimated that over 500,000 activated carbon filter units have been installed in private homes. Yet, there has never been any known public health problem related to or involving microbial contamination of such home filter units.

Recently, it has been speculated that microbial buildup in activated carbon filter units could represent a health hazard (11). In view of the long-term experience to the contrary, a study was undertaken of the effect of an activated carbon filter on the microbial quality of drinking water. Data were obtained not only from laboratory experiments, but also from filter units that had been installed in private homes.

(Presented in Atlantic City, N.J., on 5 May 1976 at the Annual Meeting of the American Society for Microbiology [J. Fiore and R. Babineau, Abstr. Annu. Meet. Am. Soc. Microbiol. 1976, Q39, p. 197].)

MATERIALS AND METHODS

Collection and treatment of water samples. A volume of 0.1 ml of 10% (wt/vol) sodium thiosulfate solution was added to each 125-ml sampling bottle before sterilization at 121°C for 15 min to provide an approximate concentration of 10 mg/100 ml of sample for neutralization of residual chlorine. Water samples in 100- to 200-ml quantities were obtained from each filtering unit. Just before making dilutions, the samples were shaken vigorously 25 times. Tenfold dilutions were then prepared by transferring 10-ml quantities to 90 ml of phosphate-buffered distilled water (pH 7.2). Pour plates (two replicates per dilution) were prepared with a 1-ml quantity of each of three appropriate dilutions and plate count agar (Difco Laboratories, Detroit, Mich.). Plates were incubated at 30°C for 48 h. We chose 30 instead of 35°C for our plate count experiments because it has been our experience that this incubation temperature is more suitable than 35°C for supplying the growth of a wide variety of water-borne microorganisms.

In certain cases, small numbers of bacteria were detected by filtering 100 ml of sample through a membrane filter with a pore size of 0.45 μm. The membrane was transferred to a sterile pad saturated with enrichment broth (lauryl tryptose broth) and incubated for 2 h at 30°C. The membrane was then transferred to a fresh pad saturated with plate count broth (Difco) and incubated for 48 h at 30°C.

Bacterial colonies were enumerated and reported as colony-forming units per milliliter of sample. Bacterial isolates were identified with selective differential media (API-20E; Analytab Products, Inc., Plainview, N.Y.).

Residual chlorine in water samples was determined by iodine-thiosulfate titration (1). Chlorine levels in influent waters ranged from 0 to 1.0 μg/ml, and in effluent waters chlorine was not detectable.

Presumptive tests for total coliform bacteria were carried out in lactose broth at 35°C for 48 h, using standard techniques (1). Three primary fermentation tubes per sample were used. Each tube received a 1-ml portion of the sample. Portions of medium in those primary fermentation tubes that contained gas from bacterial growth were transferred with a loop to brilliant green-lactose-bile broth. Incubation was at 35°C for 48 h to confirm the presumptive test. For the 0-, 1-, 3-, 4-, and 11-week samples (see Table 5), representative brillant green-lactose-bile cultures that contained gas were inoculated to selective differential agar media for isolation and identification of bacteria present in these cultures. EC broth (Baltimore Biological Laboratory, Cockeysville, Md.) was used to determine if fecal coliforms were present (1), but none were detected.

Filter type. Throughout these studies, the AMF Cuno AP 200 filter was used. It contained an AP 217 filter cartridge, which consists of three sections: resin-bonded cellulose-fiber filter media at the inlet, activated carbon through the bulk of its body, and, finally, another resin-bonded cellulose network at the outlet. This is a dual-purpose filter, which removes objectionable tastes and odors as well as dirt, rust, and sand.

Estimation of numbers and types of microorganisms in activated carbon from unused filters. For estimation of numbers and types of microorganisms in activated carbon from unused filters, activated carbon and filter media samples were aseptically removed from unused filter units. The most-probable-number tehnique, as described in the *United States Pharmacopeia* (10), was used to determine the total count of microorganisms. Initial suspensions were prepared with 10 g of ground activated carbon-filter media mixture added to 90 ml of pH 7.2 potassium phosphate buffer. Tubes containing fluid soybean-casein digest medium were then inoculated as specified (10). Petri plates containing soybean-casein digest agar and soybean-casein digest agar with 5% (vol/vol) sheep erythrocytes were streaked with inocula from positive most-probable-number tubes. Organisms were identified by using selective differential media.

RESULTS

A study of the microbiology of home water filters should include an examination of the microbial content of the filter and its media, and the water before and after filtration. Each of these factors is considered below.

Microbial content of unused filters. The results of the most-probable-number tests for unused activated carbon filters are given in Table 1. These filters were considered as new manufacture. No gram-negative bacteria were detected in any of the filters examined. Only gram-positive spore-forming rods, gram-positive cocci, and some molds were isolated from the filters examined in this phase of the study.

Microbial content of activated carbon-filtered water. To examine the effect of filtration on the microbial content of water, studies were carried out with filtered water and also with unfiltered water under laboratory conditions simulating home usage. This study extends that of Wallis et al. (11), where samples were examined for microbial content only in the morning and not throughout the day.

The present studies were conducted in the laboratory under completely controlled conditions, using the natural microbial flora existing in the source water. A manifold system was constructed (Fig. 1), using three AP 200 units equipped with AP 217 filter cartridges and one AP 200 housing with no cartridges. For this particular experiment, the fifth housing shown in the figure was blanked off. All the units ran off a single source of city water under a flow of 0.64 liter/unit per min. The system was equipped with a timing device that allowed for a 2-min-on and 3-min-off cycle simultaneously in all units. The sampling procedure was as follows. In the morning, with the timing device having been left in the off position overnight, the water was turned on, and, with the water continuously running, samples were obtained for each unit at zero time (first out) and 2, 5, and 10 min. The timer was then turned on and left on for the normal working day (8 h), operating at the 2-min-on and 3-min-off cycle. During this interval, samples were also taken at 2, 4, 6, and 8 h by allowing the first 100 ml of the on cycle to pass and taking the next 200 ml. The timer was then turned off (after 8 h), and the water flow stopped. Sampling was then repeated the next day, after this dormant period of water flow. Plate counts on all samples were performed as described in Materials and Methods. Samples were taken for 3 consecutive days (days 8, 9, and 10) after conditioning the system for 7 days before sampling.

In view of the fact that water use can influence the total count, it is important that the chosen rate of water flow is not too high or too low. It should be typical of normal household usage. With the water flow and cycle times noted above, the flow per unit per hour amounted to 15.14 liters. It is felt that this is more typical of normal household use for an average family of four (2, 7) than the substantially lower volumes used in some of the other studies of this type (11).

The experimental data are presented in Table

TABLE 1. *Evaluation of numbers and types of microorganisms present in unused activated carbon filters*

Filter no.[a]	Organisms isolated: Types	Organisms isolated: MPN[b]/g
1[c]	*Bacillus* sp., gram-positive cocci	<0.3
2[c]	*Bacillus* sp.	<0.3
3	*Bacillus* sp., *Trichosporon* sp.	<0.3
4	*Bacillus* sp.	<0.03
5	*Bacillus* sp., gram-positive cocci	<0.3
6[c]	*Bacillus* sp., gram-positive cocci	<0.3
7[c]	*Bacillus* sp., gram-positive cocci	<0.3
8	*Bacillus* sp.	<0.3
9	*Bacillus* sp.	<0.3
10	*Bacillus* sp.	<0.03

[a] Filters were manufactured less than 3 months before these analyses were performed.
[b] MPN, Most probable number.
[c] Damaged outer wrapper when received.

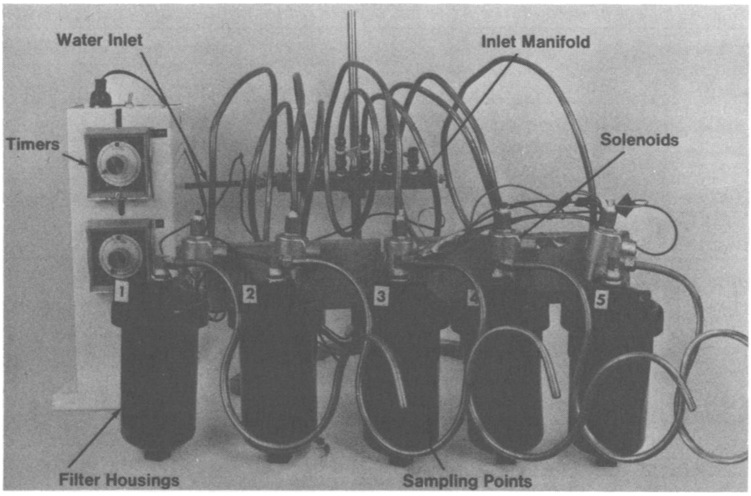

FIG. 1. *Laboratory test system: manifold system used to examine the effect of activated carbon filters on the microbial content of water.*

TABLE 2. *Effect of activated carbon on the microbial content of laboratory water*

Unit no.[a]	Time	CFU/ml of sample[b]		
		Day 8	Day 9	Day 10
1	0 min	3.8×10^4	8.3×10^3	1.6×10^4
	2 min	1.8×10^3	2.5×10^2	5.3×10^2
	5 min	1.4×10^2	1.2×10^1	7.4×10^1
	10 min	9.9×10^1	1.2×10^1	2.6×10^1
	2 h	5.8×10^1	3.6×10^1	1.5×10^1
	4 h	7.3×10^1		4.7×10^1
	6 h	2.1×10^2	1.0×10^1	2.5×10^1
	8 h	5.1×10^1	9.0×10^0	5.6×10^1
2	0 min	5.0×10^4	1.0×10^4	1.8×10^4
	2 min	1.4×10^3	5.0×10^2	4.1×10^2
	5 min	7.3×10^2	3.5×10^2	2.7×10^2
	10 min	7.8×10^2	3.1×10^2	8.6×10^1
	2 h	6.8×10^1		3.0×10^2
	4 h	2.7×10^2	5.4×10^1	5.6×10^1
	6 h	8.5×10^1	2.3×10^1	7.1×10^2
	8 h	1.5×10^2	1.0×10^2	9.7×10^2
3	0 min	1.2×10^4	2.5×10^4	5.0×10^3
	2 min	1.3×10^3	7.3×10^2	1.3×10^3
	5 min	3.1×10^3	5.5×10^2	1.2×10^3
	10 min	1.6×10^3	9.4×10^2	3.8×10^2
	2 h	2.2×10^2	2.1×10^2	5.9×10^2
	4 h	8.0×10^2	1.2×10^2	3.9×10^1
	6 h	3.4×10^2	7.8×10^1	6.7×10^2
	8 h	1.8×10^2	7.9×10^1	1.2×10^3
4	0 min	2.6×10^4	4.0×10^3	1.2×10^3
	2 min	1.5×10^3	2.9×10^2	4.1×10^2
	5 min	8.4×10^2	6.2×10^2	1.1×10^2
	10 min	1.5×10^3	4.3×10^2	9.4×10^1
	2 h	1.9×10^2	3.3×10^2	6.5×10^2
	4 h	2.0×10^2	1.4×10^2	2.0×10^0
	6 h	4.0×10^2	4.2×10^1	3.0×10^2
	8 h	1.8×10^2	2.5×10^1	6.9×10^2

[a] Unit 1 without and units 2 through 4 with the AP 217 cartridge.

[b] Samples were taken after the manifold had been operating for 7 days. CFU, Colony-forming units.

2 and indicate the following. (i) With or without an activated carbon cartridge, the microbiological pattern is the same, namely, populations increase after a period of dormancy and decrease during flushing and/or usage of the water. (ii) After 10 days, unfiltered water contained 1.6×10^4 (0 h [morning sample]), 4.7×10^1 (4 h), and 5.6×10^1 (8 h) bacteria per ml; filtered water (units 2, 3, and 4) contained no more than 1.8×10^4 (0 h), 5.6×10^1 (4 h), and 1.2×10^3 (8 h) bacteria per ml, indicating that the microbial content of filtered and unfiltered water increases to about the same level on overnight standing and, in both cases, can be reduced by flushing.

These laboratory results were essentially corroborated when activated carbon filters were installed in private homes. For these studies, the filter units were installed by a licensed plumber. The results of these experiments are presented in Table 3. Morning samples (100 ml), after overnight dormancy, were taken after at least 30 days of routine use; the bacterial counts were typically in the range of 3.0×10^2 to 3.5×10^4/ml. These values are well within the ranges reported for the laboratory studies.

During the course of these experiments, the described installations were also monitored in such a way as to ascertain the effects of a 2-min flushing period before resampling for bacterial content. The results of one such typical monitoring after at least 30 days of cartridge use are recorded in Table 4. Zero-minute samples were obtained after overnight dormancy. It can be seen that a reduction of at least about 90% in the microbial content of the water was achieved in every case.

Effect of activated carbon filtration on

TABLE 3. *Effect of activated carbon on the microbial content of home tap water*

Unit no.	Approx distance from laboratory (miles)[a]	Water source	Days after installation	Bacterial population (CFU/ml of sample)[b]	
				Influent[c]	Effluent[d]
1	7 (11.3)	Metropolitan	38	1.3×10^2	6.1×10^3
2	20 (32.2)	Metropolitan	61	1.5×10^3	3.5×10^4
3	6 (9.7)	Metropolitan	47	1.0×10^1	1.5×10^4
4	22 (35.4)	Private well	68	2.2×10^3	3.0×10^2
5	14 (22.5)	Metropolitan	47	3.0×10^5	3.5×10^4
6	10 (16.1)	Metropolitan	55	1.0×10^4	1.9×10^3

[a] Number in parentheses is approximate equivalent in kilometers.
[b] Samples were the first 100 ml of water taken from the tap in the morning. CFU, Colony-forming units.
[c] Unfiltered water.
[d] Filtered water.

TABLE 4. *Effects of 2-min flushing on the microbial content of filtered home tap water*

Unit no.[a]	Bacterial population (CFU[b]/ml of sample)	
	0 min	2 min
1	6.1×10^3	2.3×10^2
2	3.5×10^4	1.2×10^3
3	1.5×10^4	2.5×10^3
4	3.0×10^2	6.0×10^0
5	3.6×10^4	1.4×10^3
6	8.8×10^4	9.5×10^3

[a] These are the same units shown in Table 3.
[b] CFU, Colony-forming units.

the coliform content of well water. An earlier study projected that activated carbon filters may concentrate potentially pathogenic bacteria from a contaminated water source and allow them to multiply to a point where they could cause illness (11). During our studies, it was discovered that one household (unit 4, Tables 3 and 4) had a water supply that contained coliforms but no fecal coliforms. The water was monitored over an 11-week period, and the results are presented in Table 5. It is apparent that the number of bacteria in the first 100 ml of filtered tap water sampled in the morning did not vary significantly from the counts found in unfiltered influent well water throughout the 11-week study. In addition, the numbers of coliforms found in both filtered and unfiltered water were equivalent and remained so for the 11-week period. The coliforms did not colonize the filter system and grow to levels above those found for the unfiltered water. This finding has been recently confirmed by similar coliform studies reported by Johnston et al. (8).

DISCUSSION

The use of activated carbon for over 15 years to remove taste and odors from home drinking water has not been associated with any known microbiological problems. The results presented in this study indicate that only gram-positive spore-forming bacilli, gram-positive cocci, and some molds were isolated from activated carbon home water treatment filters after manufacture and before use. No gram-negative bacteria were detected in any of the unused filters examined. From a nutritional standpoint, these results are as expected. Because of the low available water and lack of usable organic matter, only organisms that can survive in a dormant form would be expected to be recovered from this type of product. *Bacillus* species, mold spores, and gram-positive cocci have been known to survive long periods in a dormant condition, as can occur in unused filters. Since these organisms are normal, ubiquitous inhabitants of soil and dust, their most likely mode of entry is through airborne dust as it falls on the filtering material from the air. This also would explain the relatively low numbers detected by the most-probable-number procedures. These organisms are generally not considered to be harmful to man.

It is known that the microbial flora of a finished water at its point of use may include a large variety of genera and species (6). The use of activated carbon filters has not been found to significantly alter this pattern either in types or numbers, even when the organisms have been coliforms. Thus, the expectations of other authors (11) that potentially pathogenic bacteria might multiply to high concentrations in carbon filters were not substantiated by these experiments. Indeed, the low level of coliforms in the water that passed through unit 4 (Table 5) remained relatively constant for the entire 11-week test period. In this regard, a study by Johnston and Burt (8) revealed that tap water seeded with coliforms contained less of these organisms after it was flushed through an activated carbon filter. They concluded that, whereas bacteria indigenous to tap water may survive and multiply in the carbon bed, coliforms may have been at a competitive disadvantage.

There is little doubt that home water filters can elevate the microbial content of water. However, our results show that unfiltered standing water can also increase in microbial content. In

TABLE 5. *Microbiological analysis of well water filtered through activated carbon*[a]

Weeks after installation	Sample: Time (min)	Sample: Source[e]	Bacterial population (CFU[b]/ml)	Organisms identified[c]	Total coliforms (MPN index/ml)[d]: Presumptive	Total coliforms (MPN index/ml)[d]: Confirmed
0	0	In	2.0×10^3	2, 6, 7, 8	3.3×10^{-1}	3.3×10^{-1}
	0	Out	8.0×10^2	2, 6, 7	7.9×10^{-1}	7.9×10^{-1}
	2	Out	2.9×10^2	2, 3, 5	1.3×10^0	1.3×10^0
1	0	In	3.8×10^2	5, 6, 9	2.4×10^0	2.4×10^0
	0	Out	8.3×10^2	2, 6, 9	5.4×10^0	3.5×10^0
	2	Out	4.2×10^2	2	7.9×10^{-1}	7.9×10^{-1}
3	0	In	6.4×10^1	ND	2.4×10^0	7.9×10^{-1}
	2	In	2.8×10^1	2, 5	3.5×10^0	1.7×10^0
	0	Out	1.7×10^2	ND	1.7×10^0	1.1×10^0
	2	Out	6.9×10^1	ND	3.5×10^0	3.5×10^0
4	0	In	2.1×10^2	4, 7	7.0×10^{-1}	7.0×10^{-1}
	2	In	5.6×10^1	1, 7	2.4×10^0	2.4×10^0
	0	Out	3.0×10^1	ND	7.9×10^{-1}	4.9×10^{-1}
	2	Out	2.5×10^1	2	3.3×10^{-1}	3.3×10^{-1}
11	0	In	1.4×10^2	ND	7.9×10^{-1}	2.3×10^{-1}
	2	In	5.3×10^1	ND	2.3×10^{-1}	2.3×10^{-1}
	0	Out	1.4×10^1	ND	7.0×10^{-1}	2.3×10^{-1}
	2	Out	1.1×10^1	ND	4.9×10^{-1}	$<2.0 \times 10^{-2}$

[a] Well water samples taken from unit 4 (see Tables 3 and 4).

[b] CFU, Colony-forming units.

[c] 1, *Aeromonas hydrophilia;* 2, *Citrobacter freundii;* 3, *Enterobacter aerogenes;* 4, *Erwinia* sp.; 5, *Klebsiella oxytoca;* 6, *Klebsiella ozaenae;* 7, *Klebsiella pneumoniae;* 8, *Pseudomonas fluorescens;* 9, *Pseudomonas* sp.; ND, not determined.

[d] No fecal coliforms detected. MPN, Most probable number.

[e] In, Unfiltered water; Out, filtered water.

itself, an increase in total microbial content of potable water, particularly to the levels found in this study, does not represent even a potential microbiological problem.

To put the question of total microbial content into proper perspective, it is well to review this aspect of some common food products. A good example of the daily ingestion of high numbers of viable organisms that are not harmful is the consumption of yogurt by people numbering into the hundreds of thousands. According to Kroger and Fram (9), a good plain yogurt, which contains *Streptococcus thermophilus* and *Lactobacillus bulgaricus* in a roughly 1:1 ratio, will show total plate counts of 3×10^7 to 4×10^9/g at day 2 after purchase and will continue to increase in counts from day 2 to day 10 after purchase, even under constant refrigeration. Another example of a material being consumed on an even greater scale and allowed under U.S. federal regulations to contain a total plate count as high as 2×10^4/ml and a total coliform count of up to 10/ml is grade A milk. It is apparent that an elevated total microbial number is not, of itself, a problem.

It is notable that the Food and Drug Administration (5) has declined to set standards for the total number of microorganisms allowable in bottled water because there is no evidence that total count is directly related to a potential microbiological problem. More recently, the Environmental Protection Agency, which had originally proposed a standard plate count of 5×10^2/ml as one of the primary drinking water standards (3), eliminated this standard from the final regulations on the basis that it was "not justified by the available data," although it still believes "that the standard plate count is a valid indicator of bacteriological quality of drinking water and recommends that it be used in appropriate cases in conjunction with coliform tests as an operational tool" (4).

In conclusion, our data indicate that the activated carbon home water filters used in these experiments and not intended for use as microbial filters appear to be microbiologically neutral devices in that they neither improve nor detract from the microbial quality of water. In this study, water supplies that were microbiologically safe without filtration were microbiologically safe with filtration.

LITERATURE CITED

1. **American Public Health Association.** 1971. Standard methods for examination of water and waste water, 13th ed. American Public Health Association, Inc., New York.

2. **Clark, B. D.** 1967. Houseboat wastes—methods for collection and treatment. U.S. Department of the Interior, Pacific Northwest Water Laboratory, Corvallis, Ore.
3. **Environmental Protection Agency.** 1975. Interim primary drinking water standards. Fed. Regist. **40:** 11990–11998.
4. **Environmental Protection Agency.** 1975. National interim primary drinking water regulations. Fed. Regist. **40:**59566–59588.
5. **Food and Drug Administration.** 1973. Bottled water. Fed. Regist. **38:**32558–32565.
6. **Geldreich, E. E., H. D. Nash, D. J. Reasoner, and R. H. Taylor.** 1972. The necessity of controlling bacterial populations in potable waters: community water supply. J. Am. Water Works Assoc. **64:**596–602.
7. **Goldstein, S. N., V. D. Wenk, M. C. Fowler, and S. S. Poh.** 1972. A study of selected economic and environmental aspects of individual home wastewater treatment systems. Mitre Corp., McLean, Va.
8. **Johnston, P. R., and S. C. Burt.** 1976. Bacterial growth in charcoal filters. Filtr. Sep. **13:**240.
9. **Kroger, M., and S. R. Fram.** 1975. Consumer attitudes toward yogurt. Food Technol. (Chicago) **29:**52–57.
10. **United States Pharmacopeia, 19th ed.** 1975. Mack Publishing Co., Easton, Pa.
11. **Wallis, C., C. H. Stagg, and J. L. Melnick.** 1974. The hazards of incorporating charcoal filters into domestic water systems. Water Res. **8:**111–113.